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An Algorithmic Approach to Identify the Optimum Network Architecture and WLAN Protocol for VoIP Application

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Abstract
To determine the optimal network architecture between the Basic Service Set, the Extended Service Set and the Independent Basic Service Set, this study established a new algorithm to assess Voice over Internet Protocol (VoIP) metrics of different IEEE 802.11 technologies. An important coefficient for each VoIP metric parameter has been invented to rank the different IEEE 802.11 standards and to identify the most efficient one for the VoIP application. The best overall network performance that offers good voice quality is ensured by determining the optimum network architecture and technology. Moreover, for the VoIP efficiency parameters, it meets the acceptance threshold values. This algorithm was implemented in different sizes of rooms ranging from 1×1 m to 10×10 m, and the number of nodes varied from 1 to 65. End to end delay, jitter, throughput and packet loss were the quality of service parameters used.

Keywords VoIP · QoS · Performance analysis · IEEE technologies

1 Introduction

In the communication industry, managing VoIP is a high priority at present. It is crucial to introduce real-time traffic such as VoIP over WLAN with the continuous motion of business operation and end-users towards Wireless LAN (WLAN). These days, WLAN has become famous because deployment is fast and quick [1]. By providing reliable access to the network resources and implementing real-time traffic such as video and audio in business, institutional and home networks, WLAN has become service-dominant and has increased in popularity. WLAN performance directly depends on the signal strength that operates through the air and varies from topology to topology, which has contributed to bringing about the flexibility of the network establishment, the mobility of nodes, and cost reduction [2]. In addition to voice over wireless networks, online

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platform services such as social media websites, email and file transfers influence the use of WLAN. VoIP is a mechanism for transmitting time-sensitive voice over the packet-switched network. VoIP has turned out to be a serious competitor to the traditional public switched telephone network (PSTN) [3]. However, providing precise QoS considered an issue for real-time multimedia applications such as VoIP, video over IP and online games. In order for VoIP to work adequately, the QoS parameters and characteristics performance have to be fulfilled [4].

A set of variables that impact network performance, such as wireless network architectures (BSS, ESS, and IBSS) and IEEE MAC-layer technologies, should be identified and assessed in WLANs where VoIP application has been implemented. Several studies have considered VoIP performance over WLAN standards. In Abdelrahman et al. [5] A VoIP network is optimized for deployment. VoIP application packets were sent through the RTP, TCP, and UDP protocols to get results relevant to the QoS metrics. As a finding of this experiment, the rate of packet loss over RTP was seen to be decreased. In real-time services, several efforts have been made to test metric QoS parameters set by IEEE technologies. The relationship between Enhanced Channel Access for Distribution (EPACA) and the Distributed Coordination System (DCF) is explored by researchers Cahyadi et al. [6] for three traffic services: audio, video streaming and data, by using simulator NS-3. A network stability model that would reliably represent network efficiency when network failures rake place in real-time was suggested by Dai and Xu [7] and offers recommendations on how to preserve network stability. The partnership within VoIP codec and QoS parameters has been investigated by Labyad et al. [8] To explore the best VoIP codec for performance over the IP network. Simultaneously, initiatives for monitoring IEEE protocols are taking place. QoS parameters such as the end-to-end delay and throughput, on the other hand, were identified by Sharma et al. [9] using two IEEE 802.11, 11g technologies and proved that IEEE 802.11a outperform the architecture of the BSS network.

Several schemes have been proposed to enhance VoIP services [10, 11]. In Hussain et al. [10] VoIP services were evaluated across an existing network. As a finding of the study, the rate of packet loss was said to decrease, whereas a new approach was introduced by Dong et al. [11] To improve VoIP services and to assure an improvement in VoIP capacity.

Various efforts have been developed to evaluate the VoIP QoS parameters for the different number of nodes that are configured over IEEE technologies [12–14]. Pérez et al. [12] introduced a simulation scenario to evaluate the IEEE 802.11e standard for a number of VoIP nodes that varied from 5 to 45 nodes; as a result of this simulation scenario, it was shown that there is an increase in average delay for VoIP application. Over two IEEE technologies (802.11g and 11e) in AlAlawi and Al-Aqrabi [13], two QoS VoIP variables, end-to-end delay and throughput, it has been shown that VoIP services have improved over the improved IEEE standard. Nevertheless, the performance metrics of VoIP QoS were examined by Sllame et al. [14] utilising different routing protocols. Only 15 nodes were used without taking into account the effects of physical layer technologies, spatial distributions or network architecture.

Recent studies have examined network architectures and real-time protocols and optimized them with VoIP services [15, 16]. To research the impact of different VoIP codecs, the authors in Ifijeh et al. [15] developed an ESS network architecture; the effects of different codecs on a VoIP over WLAN were studied in this article. Since two access points have been used to configure the scenarios, ESS is the network architecture configured to set up the network. Furthermore, to boost IEEE 802.11e in an attempt to optimise the QoS for voice and video services, a new approach was developed over the Ad hoc wireless network by Lakrami et al. [16].

In this paper, we have generalized our previous work [17–19] as a stand-alone service on Internet application deployment, where configurations and implementations are all unique to a VoIP application, including IEEE 802.11n technology and more nodes (41–65) for that structure. The study was carried out for all six IEEE 802.11 technologies on the effect of node Spatial Distribution (i.e., Circular, Random, Uniform) on network performance. This specific area of study was not seen in the literature. In addition, the accessibility of IBSS, BSS, and ESS has grown in the complexity of determining which network architecture is appropriate to use to provide optimum network quality with regard to the allocated wireless network resources.

This paper discusses the potential for any influence on network efficiency by using a variety of nodes and IEEE physical layer technologies applied through various spatial distributions.

The subsequent sections of this article are organized as follows. Section 2 introduces the fundamentals and principles of IEEE physical layer technologies. Section 3 presents the details of the proposed algorithm along with mathematical calculations. In Sect. 4 the results are analysed and evaluated in detail, while Sects. 5 and 6 present a comparative study and the conclusion.

2 IEEE 802.11 Principles Outline

2.1 IEEE 802.11 Technologies

The 802.11 group has been developed as a WLAN technology by the Institute of Electrical and Electronics Engineers (IEEE). IEEE 802.11a is in 5 GHz and 802.11b is at 2.4 GHz, and IEEE 802.11b supports up to 11Mbps transmission and IEEE 802.11a delivers a performance speed of 54 Mbps. By implementing orthogonal frequency multiplexing division (OFDM) in the 2.4 GHz band, IEEE 802.11g allows transmission speeds of up to 54 Mbps. IEEE 802.11n uses Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) techniques to achieve transmission speeds of up to 300 Mbps. In the case of using a channel bandwidth up to 40 MHz, IEEE 802.11n can provide transmission speeds of up to 600 Mbps [20]. IEEE 802.11 standard does not support time-sensitive voice applications but only best-effort services. After several refinements and with the increasing call for real-time multimedia applications, a new amendment named IEEE 802.11e was designed [21]. Table 1 shows the main differences between the IEEE 802.11 standards.

Table 1 Summary of IEEE 802.11 standards

Standard	802.11	802.11a	802.11b	802.11g	802.11n
MAC protocol	DCF	DCF	DCF	DCF	EDCA
Data rate (Mbps)	1, 2	Up to 54	1, 2, 5.5, 11	Up to 54	Up to 600
Modulation	FHSS, DSSS	OFDM	DSSS	ERP-OFDM	MIMO-OFDM
Frequency band (GHz)	2.4	5	2.4	2.4	2.4 & 5
Channel width (MHz)	20	20	20	20	20, or 40
Number of spatial streams	1	1	1	1	1, 2, 3, or 4

2.2 Infrastructure of IEEE Networks

The main component of 802.11 WLAN is BSS [22]. BSS is a wireless network operated by a central coordination or access point (AP) system. All stations may exchange information with any station within a given range of base stations. A set of infrastructure BSSs is called an ESS. Infrastructure networks shall be built using APs that regulate the communication process. Instead, the IBSS network is a small group of BSS-nodes operating without the assistance of centralized coordination [23].

2.3 Performance Measurements of QoS and Importance Coefficient for VoIP

The QoS metrics for multi-service applications are defined by performance metrics. The criteria for fulfilment of each application (acceptable thresholds) is defined for each QoS metric parameter [24, 25] as shown in Table 2, reflecting main QoS specifications and guidelines for each application (bearer traffic).

The following QoS metric measurements explicitly impact the efficiency of the best-effort applications:

- *Packet End-to-End Delay (s)* The transmission rate from node A to node B on the network is being used by data/voice.
- *Page Response Time (s)* The time necessary to download the whole page including all inline objects embedded.
- *Throughput (bit/s)* The cumulative rate at which packets are transmitted at a given time from the source to the destination.
- *Traffic Sent (packet/s) and Traffic Received (packet/s)* utilised measure the loss rate of packets, which is the proportion of packets lost further along the communication path, once the transmitter sends the packet to the network.

It is noteworthy that every VoIP application parameter has a significant coefficient (VIP), in terms of its impact on service quality. Table 2 demonstrates the consistency importance and the associated threshold values for VoIP application for each QoS parameter. These qualitative considerations (H = 1, M = 0.5 and L = 0.1) to be taken into account in the simulation should be converted into numbers.

Table 2 VoIP QoS metric parameters importance

QoS for VoIP	Delay (s)	Jitter (s)	Throughput (kbps)	Racket loss rate (%)
Importance	H	H	M	L
Threshold	0.15	0.04	45	5

H high, *M* medium, *L* low

3 Algorithm Proposed: Selection of Protocol and Architecture for Network

3.1 Development Schemes (Environment Simulation)

This paper uses an OPNET model of simulation [26] to construct and evaluate all scenarios. OPNET Modeler offers the ability to easily explore network communication, facilities, architectures and protocols.

We have taken two key sources' inputs for this algorithm into account with the OPNET simulation: user configuration and technical specifications (standards). The size of the network and space distributions are described in user configurations. Technology specifications describe the technology and architectures of the physical layer.

These factors are defined in the top part of Fig. 1. Network architectures indicate how wireless nodes interconnect with each other in one of the two approaches: the existence of AP (BSS and ESS) or lack of AP (IBSS), the size of the network needed (1–5, 6–10, 11–20, 21–40 and 41–65) and spaces allocations, which topological distribution of wireless implemented nodes is defined (circular, random, uniform). IEEE MAC Technologies describes the IEEE 802.11 technologies that are used to build several possible scenarios. Figure 2a–c show some of these implemented scenarios.

The literature [12–14] is consistent with the number of nodes known to be up to 65. On the other hand, the findings obtained using these five groups of nodes were considered suited to preserve the consistency of network efficiency, that is more nodes within the network, which means that relatively few traffic volumes cause service quality deterioration due to bandwidth ability of the fixed network.

The IEEE standards/technologies used were 802.11, 11a, 11b, 11g, 11e and 11n. The protocols used and the applications settings for the simulation are listed in Table 3.

3.2 Structure for the Computation System

In the lower part of Fig. 1, Phase II displays the system calculations and the mathematical model. QoS Threshold values for each application and cumulative distribution function (CDF) were used to input the mathematical calculations of the algorithm.

There will be mathematical calculations to see how many performance metrics have been achieved for each scenario. In order to illustrate the calculations and the results for each of the projects above, the following criteria must be met.

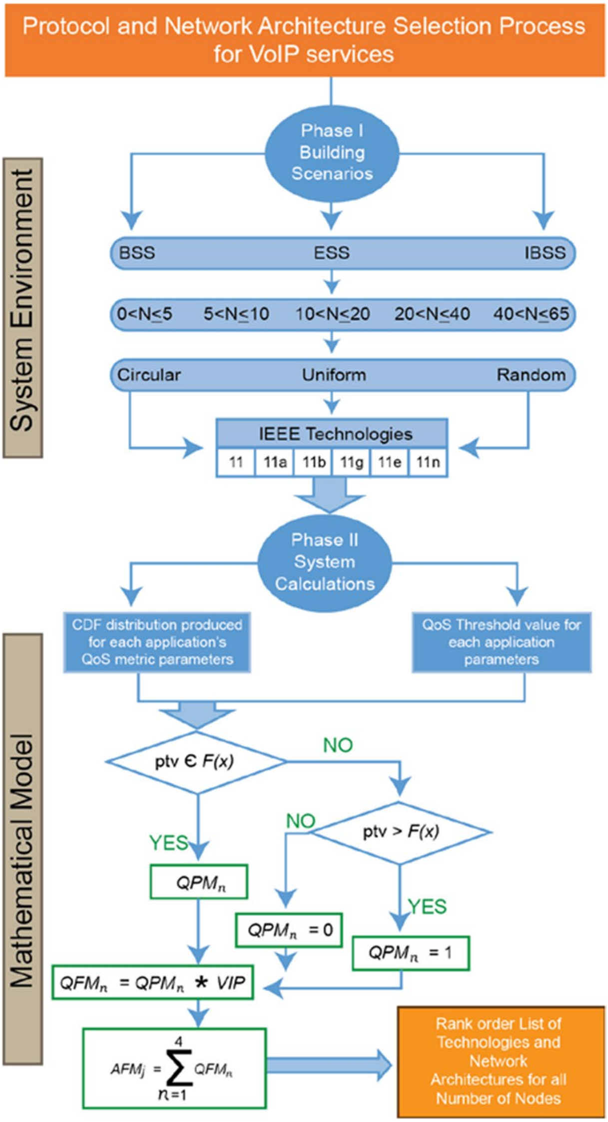
- *QoS Performance Metric (QPM)* As shown in Fig. 3, the value produced by the use of the QoS metric Parameter Threshold value (PTV) application in CDF distribution $F(n)$, for each performance criterion n, that is expressed by (1).

$$QPM_n = F(ptv) \tag{1}$$

- *QoS Fitness Metric (QFM)* The weighting value for QPM for each QoS metric parameter generated by the use of (H=1 and M=0.5 and L=0.1), is expressed by (2).

$$QFM_n = QPM_n * VIP \tag{2}$$

Fig. 1 Flowchart of the proposed algorithm



- Finally, the Application Fitness Metric (AFM) is measured, and all QFMs are aggregated with n application QoS metric parameters (delay, jitter, throughput and losses), for j IEEE 802.11 technology, as expressed by (3).

$$AFM_j = \sum_{n=1}^{4} QFM_n \tag{3}$$

- The rank order of the five IEEE technologies will be generated for every network architecture based on AFMs.

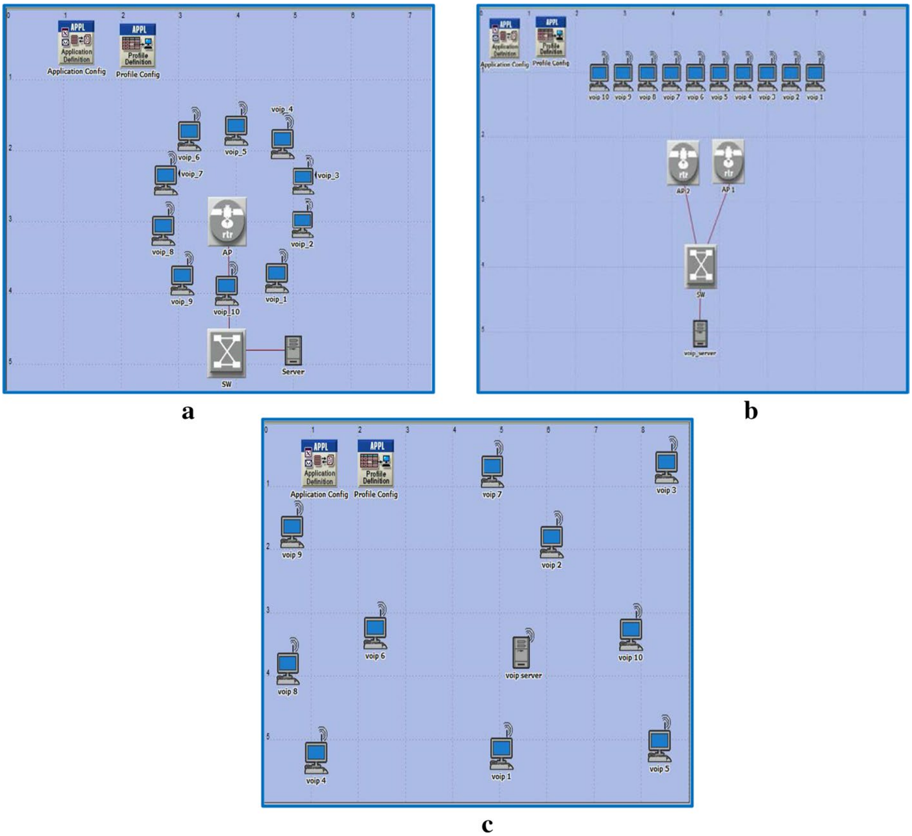


Fig. 2 Design of the three network architectures across three spatial distributions for VoIP. **a** Basic service set (BSS), **b** extended service set (ESS), **c** independent basic service set (IBSS)

As stated earlier, CDF distribution $F(n)$ [27] will be generated from the OPNET modeller simulation and then analysed for PTV in all applications by QoS metric parameters:

1. If $PTV \in F(n)$ For this metric parameter, it means PTV's CDF distribution has a particular value equal to QPM. In order to produce QFM, QPM is weighted by VIP. Then all QFMs are added to AFM that is used to categorize IEEE 802.11 technologies.
2. If $PTV > F(n)$ It implies that the value of QPM is equal to 1 and QFM has been generated.
3. If $PTV < F(n)$ QPM equals null and QFM is initialized.

The resulting value for VoIP QoS application will lead to filling out Table 4, which ultimately can lead to a rank of IEEE technologies for each architecture in the network. All VoIP QoS metric application is computed, except for the packet loss parameter, as outlined in the previous sections. OPNET Modeler is programmed to generate a Boolean value (0.0 or 1.0) resulting from a packet loss parameter that corresponds to packet acceptance or rejection. But for the packet loss, this work needs a numerical value.

Table 3 Simulated application and protocols

Parameters	Values
MAC layer	IEEE 802.11 (FHSS) IEEE 802.11a (OFDM) IEEE 802.11b (DSSS) IEEE 802.11g (OFDM) IEEE 802.11e (QoS) IEEE 802.11n (MIMO-OFDM)
Voice frame per packet	1
Application	Voice
Codec	G.711
Compression and decompression delay	0.02 s
Types of service (TOS)	Interactive voice

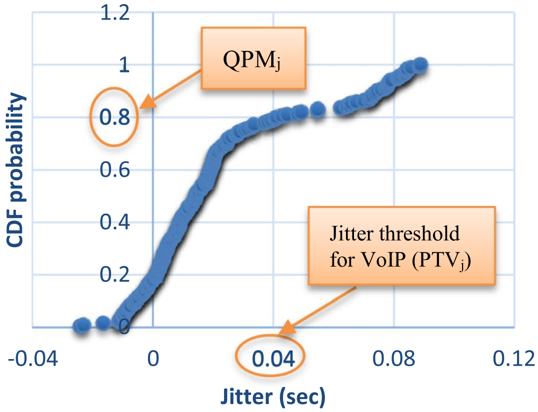


Fig. 3 QPM for jitter

Table 4 Calculation for VoIP QoS metrics (end to end delay, jitter and throughput)

Technology	VOIP				AFM	Technology rank order
	Jitter	Delay	Throughput	Packet loss		
802.11	QFM_J	QFM_D	QFM_{TH}	QFM_{PL}	AFM_{11}	Technology1
802.11b					AFM_{11a}	Technology2
802.11a					AFM_{11b}	Technology3
802.11g					AFM_{11g}	Technology4
802.11e					AFM_{11e}	Technology5
802.11n					AFM_{11n}	Technology6

A code for a method for calculating the packet loss percentage for each application was developed using MATLAB software. This is directly related to each application to the OPNET Modeler to generate a particular percentage of packet loss. Application packet loss rate ω_i for a node i is the proportion of the packet lost ki to the overall packet ρ_i times 100%, as expressed by (4).

$$\omega_i = \left(ki/\rho_i\right) * 100\% \tag{4}$$

To generate the total number of received and sent packets, the traffic received/sent rate of OPNET Modeler should be integrated and offered as a CDF illustration.

4 Implementation of the Algorithm and Mathematical Calculations

Firstly, it is necessary to establish the QPM, which is the value generated for VoIP in the CDF, applying the appropriate threshold to every performance criterion (QoS parameter).

The value QFM provided by QPM weight for each VoIP QoS parameter (as defined by its importance). For every IEEE technology, the final step would be to calculate the AFM. The algorithm and its calculations are described by the following example. Three separate projects should be constructed at the initial stages for each of the three major network configurations concerning the spatial distributions of the workstations (circular, uniform, random) as follows:

A. *BSS Projects* (BSS_10_100VOIP_C, BSS_10_100VOIP_U, BSS_10_100VOIP_R).
B. *IBSS Projects* (IBSS_10_100VOIP_C, IBSS_10_100VOIP_U, IBSS_10_100VOIP_R).
C. *ESS Projects* (ESS_10_100VOIP_C, ESS_10_100VOIP_U, ESS_10_100VOIP_R).

Six scenarios for the six IEEE physical layer technologies (802.11, 11a, 11b, 11g, 11e, and 11n) will be constructed in each project.

BSS network setup, beginning with the first case study. For the six IEEE technologies, six scenarios are going to be constructed along with all three spatial distributions. There are, therefore, six separate scenarios in each spatial distribution, each of which sets up 10 workstations equipped with each of the IEEE technologies. As a result, three major projects are BSS_10_100VOIP_C, BSS_10_100VOIP_U and BSS_10_100VOIP_R in this network configuration, every project is equipped with six scenarios relating to the six IEEE technologies.

Through addressing one of these projects, the scheme of this work and its algorithms will be explained. To take the circular one that is designed with the 802.11n technology scenario. The name of the project is BSS 10 100VOIP C, 802.11n is the physical layer technology, and the configuration of the network is: Basic Service Set.

All ten workstations with 802.11n technology are arranged and contain one point of access, as shown in Fig. 4.

After running the six scenarios for 20 min each, the outcomes of every VoIP QoS parameter will be evaluated in the very same way. The mathematical model would be based on the 802.11n system:

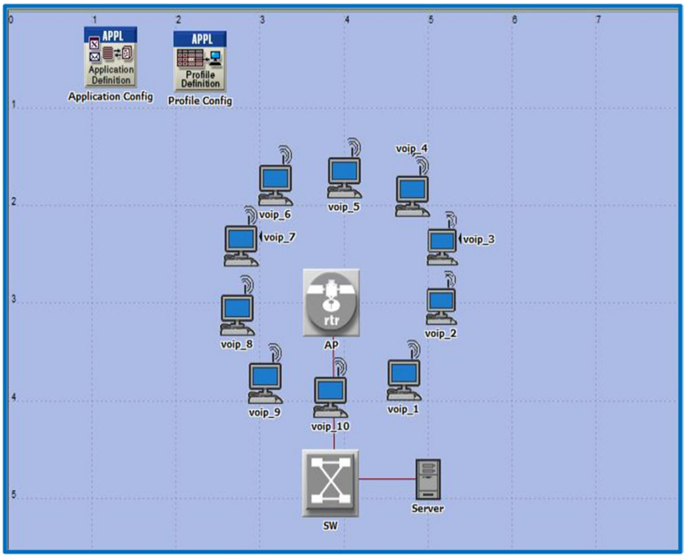
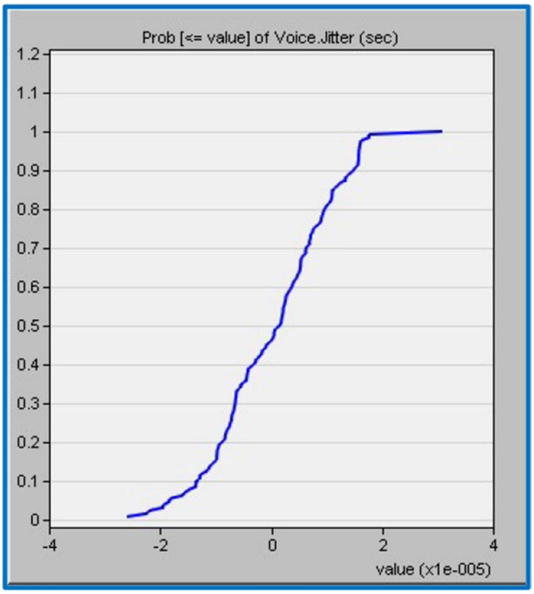


Fig. 4 Ten workstations and one AP circular distribution

4.1 Jitter

For Jitter, the VoIP threshold value is 0.04 s, and the importance of the QoS application is High, as seen in Table 2. In accordance with the outcome in Fig. 5, QPM is 1. For Jitter, the importance coefficient is High (H = 1), so the QFM is equal to 1 weighted by 1; that generates 1.

Fig. 5 Jitter result of BSS_10_100VOIP_C



4.2 Delay

For the delay, the VoIP threshold value is 0.17 s and the importance of the QoS application is high, as can be seen in Table 2. In accordance with the outcome in Fig. 6, it is also QPM = 1. High (H = 1) is the important factor for the delay, so the QFM is equal to 1 weighted by 1; that yields 1.

4.3 Inbound Throughput

As shown in Table 2, the VoIP threshold value for throughput is 45 kbps and QoS Application Importance is Medium. QPM is 0.36, according to the outcome in Fig. 7. Medium (M = 0.5) is the importance coefficient for throughput, so the QFM is equal to 0.36 weighted by 0.5; that gives 0.18.

4.4 Outbound Throughput

As shown in Table 2, the VoIP threshold value for throughput is 45 kbps and QoS Application Importance is Medium. QPM is 0.36, according to the outcome in Fig. 8. Medium (M = 0.5) is the importance coefficient for throughput, so the QFM is equal to 0.36 weighted by 0.5; that gives 0.18.

QoS statistical measurements will be made just use the same approach for other IEEE technologies (11, 11a, 11b, 11g and 11e). For all VoIP QoS parameters, Table 4 will be used to present step-by-step findings.

Two methods for calculating the percentage of packet loss to every application are used to complete this table: one using Excel Office software and the other using MATLAB software to program the code. Figure 9 displays the MATLAB code, which is used to calculate the percentage of packet losses.

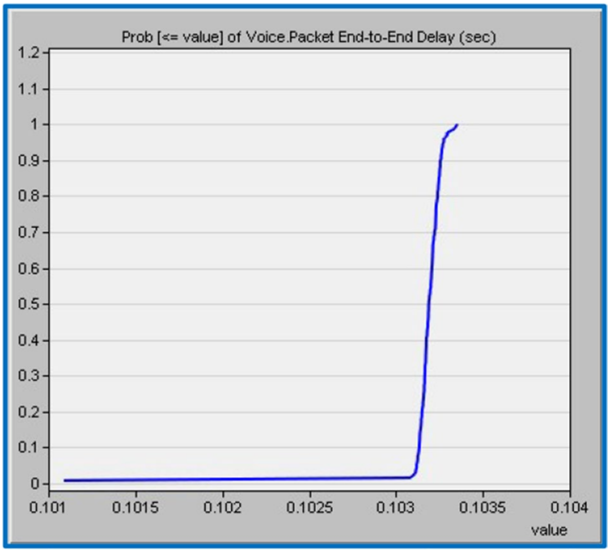


Fig. 6 Delay result of BSS_10_100VOIP_C

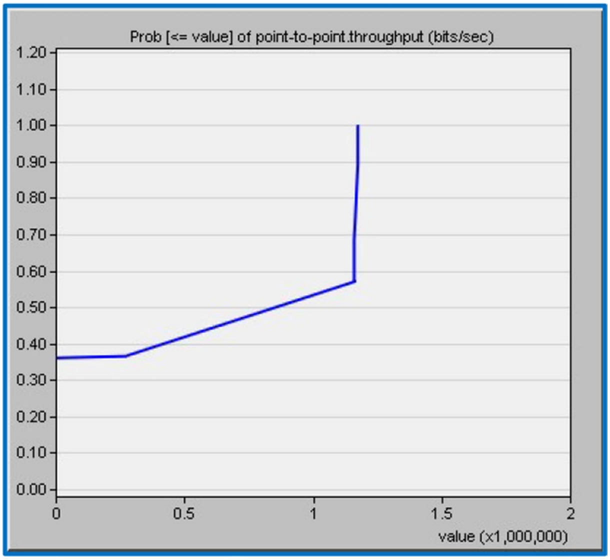


Fig. 7 Inbound result of BSS_10_100VOIP_C

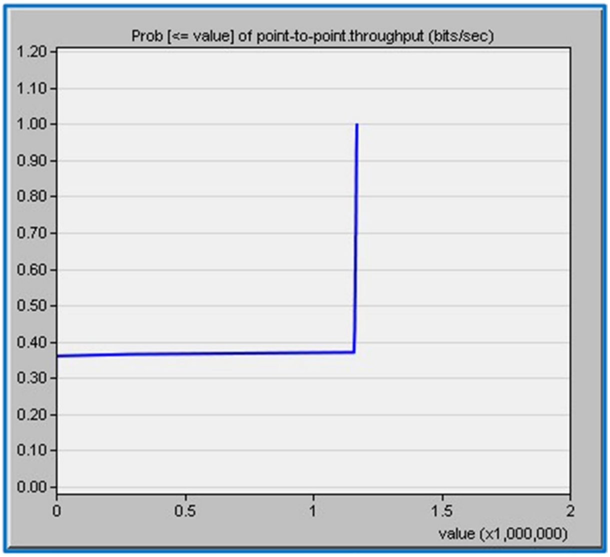


Fig. 8 Outbound result of BSS_10_100VOIP_C

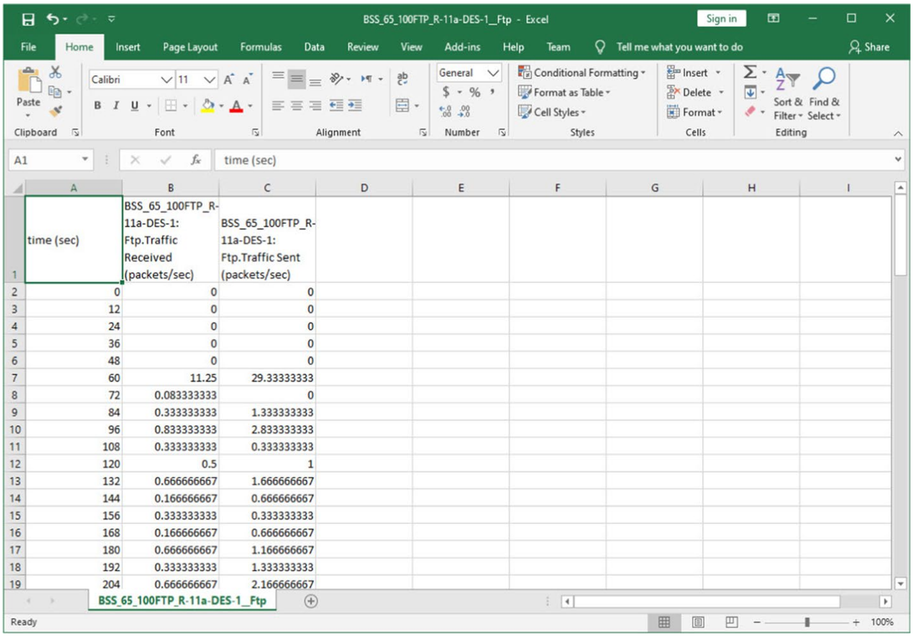
OPNET generates the result of the sent/received traffic rate before using this code and provides the ability to export and save them as a spreadsheet file, as shown in Fig. 10.

The MATLAB code will be used after saving the spreadsheet file. At the start, the code is provided with the name of the spreadsheet, including its location. The code reads all the values in all three columns; column A, representing the simulation time in seconds, column B, representing the rate of traffic received in packets/s, and column C, representing the rate of traffic sent in packets/s.

The two-line codes below represent the concept of packet loss, which divides the total number of packets transmitted minus the number of packets arrived at the destination by

Fig. 9 MATLAB code for packet loss calculations

```
filename='C:\ BSS_10_100VOIP_C-11e-DES-1__Voice.xlsx';

A = xlsread(filename,'A:A');

B = xlsread(filename,'B:B');

C = xlsread(filename,'C:C');

for i=1:1:199;

nr(i)=(B(i+1)+B(i))./2. X (A(i+1)-A(i));

ns(i)=(C(i+1)+C(i))./2. X (A(i+1)-A(i));

pl(i)=(ns(i)-nr(i))./(ns(i)) X 100;

end

[f,x1] = ecdf(pl)

plot(x1,f)
```



time (sec)	BSS_65_100FTP_R-11a-DES-1: Ftp.Traffic Received (packets/sec)	BSS_65_100FTP_R-11a-DES-1: Ftp.Traffic Sent (packets/sec)
0	0	0
12	0	0
24	0	0
36	0	0
48	0	0
60	11.25	29.33333333
72	0.083333333	0
84	0.333333333	1.333333333
96	0.833333333	2.833333333
108	0.333333333	0.333333333
120	0.5	1
132	0.666666667	1.666666667
144	0.166666667	0.666666667
156	0.333333333	0.333333333
168	0.166666667	0.666666667
180	0.666666667	1.166666667
192	0.333333333	1.333333333
204	0.666666667	2.166666667

Fig. 10 OPNET's spread sheet for traffic sent/received rate

the total number of packets transmitted, then multiplies the sum by100%, allowing the values in both columns B and C to be integrated to produce the total number of packets sent and received.

$$nr(i) = \left(\frac{B(i+1) + B(i)}{2} \times (A(i+1) - A(i)) \right) \tag{5}$$

$$ns(i) = \left(\frac{C(i+1) + C(i)}{2} \times (A(i+1) - A(i)) \right) \tag{6}$$

The precise packet loss percentage will therefore be generated using the following code line equation:

$$pl(i) = \left(\frac{ns(i) - nr(i)}{ns(i)} \times 100 \right) \tag{7}$$

As shown in Fig. 11, this packet ratio value should be viewed as a CDF diagram to include the ability to distinguish QPM, QFM and AFM values.

The value of the VoIP threshold for packet loss is 5% and the importance of the QoS application is Low, as can be seen in Table 2. QPM is1. as per the outcome in Fig. 11. Low (L = 1) is the importance coefficient for packet loss, so the QFM is equal to 1 weighted by 0.1; this yields 0.1. The packet loss estimates for other IEEE standards (11, 11a, 11b, 11g and 11e) will be determined just use the same process. The outcomes of all QFMs, including packet loss, are shown in Table 5.

The AFMs for each IEEE technology shall be determined by aggregating QFM values that yield Table 6 as follows:

As can be seen in Table 6, the ranking list of these six technologies will be given based on AFM values. The IEEE 802.11a, 11g, 11e and 11n technologies generate the highest AFMs of 2.46 and are recommendable to use in this BSS_10 100VOIP_C project.

Fig. 11 CDF distribution of packet loss

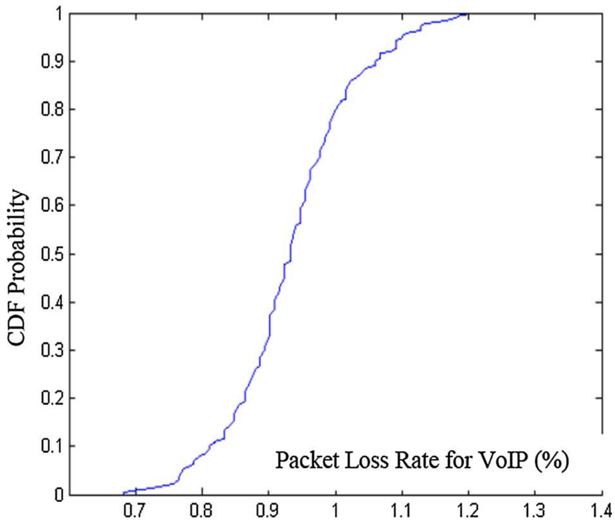


Table 5 QFMs for project BSS_10_100VOIP_C

Technology	VOIP				AFM	Technology rank order
	Jitter	Delay	Throughput	Packet loss		
802.11	1	0	0.36	0	AFM_{11}	Technology1
802.11b	1	0	0.36	0	AFM_{11a}	Technology2
802.11a	1	1	0.36	0.1	AFM_{11b}	Technology3
802.11g	1	1	0.36	0.1	AFM_{11g}	Technology4
802.11e	1	1	0.36	0.1	AFM_{11e}	Technology5
802.11n	1	1	0.36	0.1	AFM_{11n}	Technology6

Table 6 AFMs and rank order list for project BSS_10_100VOIP_C

Technology	VOIP				AFM	Technology rank order
	Jitter	Delay	Throughput	Packet loss		
802.11	1	0	0.36	0	**1.36**	802.11a
802.11b	1	0	0.36	0	**1.36**	802.11g
802.11a	1	1	0.36	0.1	**2.46**	802.11e
802.11g	1	1	0.36	0.1	**2.46**	802.11n
802.11e	1	1	0.36	0.1	**2.46**	802.11
802.11n	1	1	0.36	0.1	**2.46**	802.11b

For uniform and random distributions, the same process will be followed to rate the six IEEE technologies in order. For the other two network configurations (IBSS and ESS), framework algorithms and calculations will be implemented to decide the top overall IEEE technology (or technologies) through these two network configurations; as well as to obtain all the quantities of QPMs, QFMs, and AFMs for all VoIP QoS parameters for all six technologies in IBSS and ESS throughout the three spatial distributions. Second case study: Configuring the IBSS network. Three main IBSS_10_100VOIP_C, IBSS_10_100VOIP_U, and IBSS_10_100VOIP_R projects will be built over three spatial distributions. Six scenarios involving the six IEEE technologies will be optimized for each of them.

In this case, the same calculation method used in the first case study (BSS network configuration) to evaluate all the values of QPMs, QFMs and AFMs will also be used for all six IEEE technologies. For the three spatial distributions, Table 7 displays the rank order of IEEE technologies. Third case analysis (ESS network configuration). Three main projects ESS_10_100VOIP_C, ESS_10_100VOIP_U, and ESS_10_100VOIP_R will be developed all over three spatial distributions. Six scenarios involving the six IEEE technologies will be optimized for each.

In this case, the same calculation method used in the above two case studies (BSS and IBSS network configurations) to evaluate all the QPMs, QFMs and AFMs values for all six IEEE technologies will also be used. The rank order of WLAN technologies for circular, random and uniform spatial distributions is demonstrated in Table 8.

The framework will now provide the client with all the information required for the networking lab installation.

Table 7 AFMs and rank order list for project IBSS_10_100VOIP_C, U, R

Technology	VOIP				AFM	Technology rank order
	Jitter	Delay	Throughput	Packet loss		
802.11	1	0	0.36	0	**1.36**	802.11a
802.11b	1	0	0.36	0	**1.36**	802.11g
802.11a	1	1	0.36	0.1	**2.46**	802.11e
802.11g	1	1	0.36	0.1	**2.46**	802.11n
802.11e	1	1	0.36	0.1	**2.46**	802.11
802.11n	1	1	0.36	0.1	**2.46**	802.11b

Table 8 AFMs and rank order list for both projects ESS_10_100VOIP_C, U, R

Technology	VOIP				AFM	Technology rank order
	Jitter	Delay	Throughput	Packet loss		
802.11	1	0	0.36	0	**1.36**	802.11a
802.11b	1	0	0.36	0	**1.36**	802.11g
802.11a	1	1	0.36	0.10	**2.46**	802.11e
802.11g	1	1	0.36	0.10	**2.46**	802.11n
802.11e	1	1	0.36	0.10	**2.46**	802.11
802.11n	1	1	0.36	0.10	**2.46**	802.11b

5 Results and Performance Evaluation

In this paper, the algorithm output describes the client (user) options available based on the results table generated. Preferences suggest optimum technological performance in all three network architectures. The findings are divided into two main layers; Configuration (Network Architecture and Spatial distribution) and Technology (IEEE 802.11 standards). All modelled/simulated scenarios are for laboratory (room) dimensions from 1×1 m to 10×10 m.

The result format is displayed based on the existence of an AP; thus, the results tables are converted into two flowcharts of results: the generic flowchart and the IBSS flowcharts.

- If the network has at least one AP, the proposed algorithm will be implemented in Fig. 1 and the result will be in Fig. 12. This case applies to both layers of infrastructure (ESS and BSS). In every IEEE 802.11 technology and three spatial distributions, all scenarios function: circular, uniform and random.
- The proposed flowchart in Fig. 1 and the result in IBSS defined in Fig. 13, will be used if the network is configured without APs. The six IEEE 802.11 technologies and three spatial distributions are all covered.

The findings of both results are based on the number of nodes used to configure the required network and to work for 1 to 65 nodes environment:

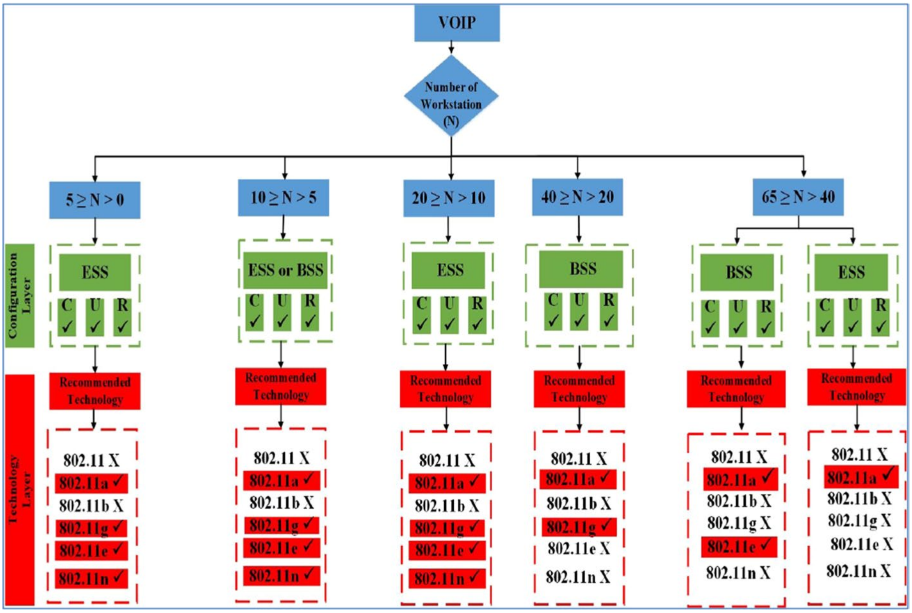


Fig. 12 Generic flowchart of the proposed algorithm using various layers

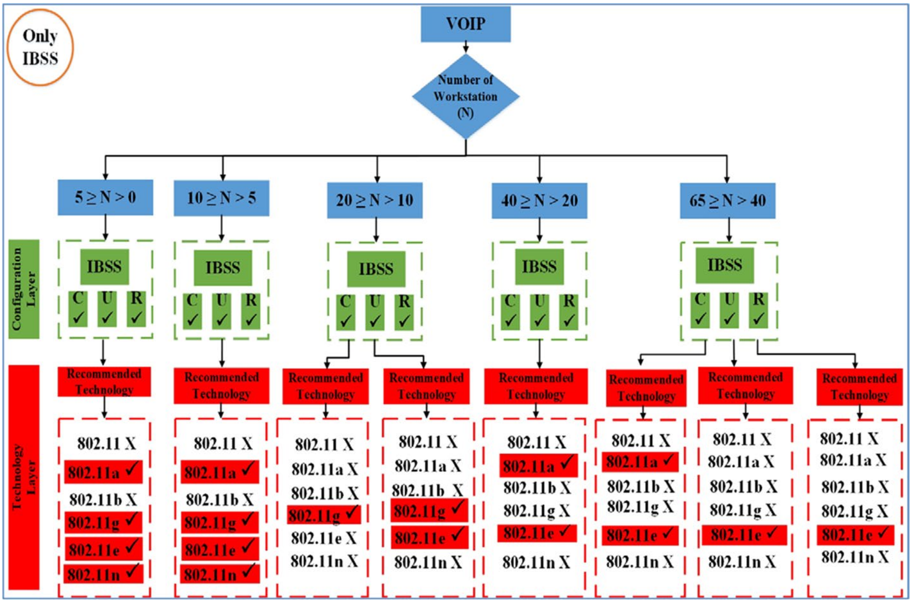


Fig. 13 Flowchart of only IBSS's results

1. If the client is going to create a small network (number of nodes less than or equal to five nodes), where $5 \geq N > 0$, in the generic flowchart, as can be seen in Fig. 12, then for all three spatial distributions, ESS is the optimal network architecture. Moreover, the

IEEE 802.11a, 11g, 11e and 11n technologies provide the optimum performance for both ESS and IBSS architectures as shown in both Figs. 12 and 13.

2. When $10 \geq N > 5$, as can be seen in Fig. 12 if the client constructs a network using a number of nodes between 5 and10, both ESS and BSS will have optimum efficiency amongst all three spatial distributions if only four technologies, namely 802.11a, 11g, 11e and 11n, are applied. In the case of the IBSS output flowchart, IEEE 802.11a, 11g, 11e and 11n technologies continue to stay optimal for all distribution patterns.
3. If the client is aiming to design a medium-sized network with the number of nodes from 10 to 20 in the third group, where $20 \geq N > 10$, then ESS offers a number of choices. The better-suited approaches are considered as IEEE 802.11a, 11g, 11e and 11n. As per the IBSS flowchart, on the other hand, IEEE 802.11g is the best technology to do this if it is circularly designed as well as both IEEE 11g and 11e technologies are favoured for uniform deployment.
4. The best architecture for this wide network is BSS in the fourth group, where $40 \geq N > 20$. Consequently, as per the information given in Fig. 12, the client has a range of choices to use. For all three spatial distributions both 802.11a and 11g technologies are optimum. In the IBSS flowchart, however, both 802.11a and 11e technologies have similar results for all spatial distributions.
5. The optimal solution is given by both ESS and BSS architectures in the general flow chart for the wide network in the fifth group, with $65 \geq N > 40$. Besides, the client has several choices once it is set up, as shown in Fig. 12. The 802.11a technology, the first choice, gives the client a satisfactory outcome in both network architectures for all space distributions. 802.11e technology, the second choice, offers maximum performance that is only optimized in the BSS architecture. On the other hand, 802.11a is the optimal technology in the IBSS flowchart, it will be used when it is circularly designed, and IEEE 802.11e works well in all spatial distributions, as seen in the IBSS flowchart.

6 Comparative Review

A comparative assessment of our proposed approach with several algorithms presented in [12–14, 28–30] will be discussed in this section. In Table 9, the following characteristics were compared and outlined, including: VoIP metric parameters, number of nodes, network architecture, IEEE technology, and simulation model simulation.

As outlined, approaches including [13, 14] measure the network on the basis of a fixed number of nodes, where metrical parameters such as throughput predominate in optimal network configuration calculations. Likewise, [12, 28] compare various IEEE technologies on a fixed number of nodes, taking into account only one network architecture, such as BSS and ESS, respectively.

Given the fact that studies like [12, 30] have used different nodes, 5–45 and 10 respectively, to incorporate their approach. However, their suggested methods have only been evaluated by using the architecture of the BSS network. Another downside combined with the [12, 13] methods is that only one IEEE standard, particularly the IEEE 802.11e standard, is used to examine the algorithm.

This article introduces the development of a new assessment parametric method to develop the optimal network configuration using three network architectures: BSS, ESS, and IBSS in contrast to those limitations above.

Table 9 Comparative results between the proposed approach and several methods available in the literature

References	Approach	VoIP metric parameters	Number of nodes	Network architecture	IEEE technology	Simulation model
[12]	Evaluate EDCA 802.11e protocol conditions for supporting QoS in an 802.11a scenario at 36 Mbps	Average delay Queue size	5–45	BSS	802.11e	Möbius™
[13]	Evaluate the performance of VoIP in 802.11 wireless networks	End-to-end delay Jitter Throughput	3–15	ESS	802.11e	OPNET
[14]	VoIP QoS performance metrics were studied using different routing protocols	Jitter LAN delay Packets size	15	IBSS	802.11b	OPNET
[28]	This work investigates the effect of different QoS techniques on VoIP performance and capacity deployment via OPNET simulation. It will also examine the highest VoIP ability for delivering accepted efficiency	Throughput Delay Jitter	5	ESS	802.11	OPNET
[29]	Evaluate the performance of various VoIP codecs using different service classes	Throughput Average delay Jitter	2, 4, 6, 8 and 10	WiMAX	802.16	NS-2
[30]	A mechanism was introduced to optimize the use of additional bandwidth to obtain optimum transmission efficiency of multimedia applications in order to enhance the scheduling of multimedia traffic in terms of channel use	End-to-end delay Bandwidth	10	BSS	802.11g 802.11e	NS2
Present study	To define the optimal network architecture, assess VoIP QoS metrics for various IEEE 802.11 technologies	Delay Jitter Throughput Packet loss	1–65	BSS ESS IBSS	802.11 802.11a 802.11b 802.11g 802.11e 802.11n	OPNET

In six different IEEE technologies, namely: 802.11, 802.11a, 802.11b, 802.11g, 802.11e and 802.11n, this procedure was performed utilising different node sizes (1–65).

7 Conclusion

In order to choose the optimal network architecture between BSS, ESS, and IBSS, this research has introduced a new algorithm for evaluating VoIP QoS metrics of various IEEE 802.11 technologies. The range of IEEE 802.11 technologies in different spatial distributions has been generated. The findings demonstrated that for all space distributions, both BSS and ESS architectures have somewhat the same performance regardless of their network size. IEEE 802.11a also offers optimal efficiency across the three spatial distributions for all node groups. Furthermore, with the 802.11a, 802.11g and 802.11e technologies, IBSS is used effectively, applying the Orthogonal Frequency Division Multiplexing (OFDM) modulation technique, which allows subchannels to simultaneously communicate different signals (picture and audio) on the same band.

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